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ECOLOGY OF NECROPHILOUS AND CARPOPHILOUS COLEOPTERA IN A SOUTHERN NEW YORK WOODLAND. PART I—OVERVIEW[1]

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Abstract.—Almost 20,000 individual Coleoptera were collected, pinned and labeled from 6 pitfall traps baited with decomposing smelt fish to attract necrophilous beetles, and 6 traps baited with decaying cantaloupe melon for carpophilous species. Six of these traps (3 pairs with each type of bait) were located on a dry slope, and 6 others in an adjacent wet valley. This field sampling was done over an 8-month period (April thru November) at Fordham University's Calder Ecology Center, Armonk, Westchester County, New York. Approximately equal numbers of beetles were taken from each bait (fish and melon), and from each habitat (slope and valley). The trapped Coleoptera were concentrated in 10 major Families (99.4%), plus 5 minor Families (0.4%) and 18 adventitious Families (0.2%). These 10 major Families also comprised 76.5% of the total 217 species trapped. The 3 most numerous Families were the Staphylinidae (37.1%), Silphidae (21.5%) and Nitidulidae (17.9%). These were followed by the Hydrophilidae (7.1%), Leptodiridae (4.9%), Histeridae (3.4%), Carabidae (2.3%), Ptiliidae (2.0%), Scarabaeidae (1.9%), Scolytidae (1.3%). Certain species were consistently attracted to fish (necrophilous) and others to melon (carpophilous). However, in both cases, many of the beetles are actually predatory, and some are general scavengers. Closely related species are usually separated temporally, most often by fortnightly periods. The geography, geology and botany of the research area are discussed as representing a southern New York woodland situated less than 50 k north of midtown Manhattan.

Introduction

The purpose of this research was to identify and enumerate the families, species and individuals of necrophilous and carpophilous Coleoptera collected at traps baited with decaying fish and melon. The field study was done in 2 ecologically distinct but adjacent areas: a dry slope and a moist

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valley in an open woodland in southern New York State. The sampling collections were made over an 8-month period from April thru November.

Decaying carrion and fruit are an important food source for many species of insect larvae and adults, especially Diptera and Coleoptera. Beetles are always of particular interest because of their sheer numbers (perhaps 300,000 species) which comprise about ⅓ of the world's known insect species. In addition, their well-known niche-specialization provides opportunities for remarkable diversity. For these reasons, Coleoptera can be studied to record food preferences between such energy sources as decaying fish and melon. Further comparisons can then be made in relation to habitat differences between a dry slope and a moist valley.

Therefore, these data were used to tabulate: (a) both the numerical and temporal relations between the species; (b) the food preferences for fish or melon; (c) the habitat association of the slope and valley. Such quantitative information concerning the relative proportions and preferences of ecologically related species should be continually added to the insect ecological literature (Matthews and Matthews 1970, Wallace 1974). Other authors such as Arnett (1970) caution further that it is not enough to know only the orders and families that occur in such habitats and have certain food preferences—but also that the species themselves, their population fluctuations and phenology must be studied. It is hoped, therefore, that the research presented here will provide basic information for use in taxonomic catalogs and future ecological studies. This *Part I* contains a summary overview of the entire project at the family level.

Materials and Methods

Field study.—The field work was done at Fordham University's Calder Ecology Center, Whippoorwill Road, Armonk, Westchester County, New York 10504. This sampling aspect of the research was conducted over an 8-month period from April thru November 1970. The field study area was 2.5 hectares, and was located in the northwest part of the 45 hectare Fordham Ecology Center. It consisted of 2 distinct but adjacent sections: a wide, western-exposed slope; a flat, narrower, stream-laced valley at the base of the slope and 27.4 m lower in altitude.

Geography, geology and pedology.—The Fordham Ecology Center is located 48.3 k north of midtown Manhattan in the County of Westchester, and ranges from 145–200 m above sea level. It is underlain by the Manhattan Prong of the igneous, highly metamorphosed Fordham Gneiss of the New England Upland (Muller 1965, Schuberth 1968), and may be of proterozoic (Precambrian) age, ca. 1 billion years old. It is about 56 k north of the southernmost terminus of the last Wisconsin glaciation which began receding about 15,000 years ago. This Fordham property is composed of the

Hollis association of soils (laid down on glacial till). It is a shallow, sandy loam 25–50 cm to bedrock, and slightly acidic, low in nitrogen and calcium, marginal in phosphorous, but adequate in potassium for tree growth. The slope is dry with shallow soil, while the valley is wet.

Botany.—The flora of the slope in this open woodland setting is dominated by typical beech (*Fagus grandifolia* Ehrhart), birch (*Betula lenta* L.) and red maple (*Acer rubrum* L.). The main associated trees are rock-chestnut oak (*Quercus prinus* L.), black oak (*Q. velutina* Lamarck) and red oak (*Q. rubra* L.). The shrub understory is composed of maple-leaved viburnum (*Viburnum acerifolium* L.), blueberries (*Vaccinium* spp.), pinxter-flower (*Rhododendron nudiflorum* Torrey), and mountain laurel (*Kalmia latifolia* L.). Some common vines, herbs, ferns, club-mosses and true mosses complete the list of the slope macrophytes.

In the valley, however, only infrequently are beech and birch found (limited to high spots), while the red maple, so common on the slope, is completely replaced by sugar maple (*Acer saccharum* Marshall). The oaks are entirely absent, perhaps because of the moist, deeper soil of the lower valley. Hence, the characteristic trees of the valley are the white ash (*Fraxinus americana* L.), black ash (*F. nigra* Marshall), bitternut hickory (*Carya cordiformis* Koch), mockernut hickory (*C. tomentosa* Nuttall), and tulip-poplar (*Liriodendron tulipifera* L.). Witch-hazel (*Hamamelis virginiana* L.) is usually a somewhat isolated species elsewhere, but in the valley it is common and attains a large size and extensive coverage. Spicebush (*Lindera benzoin* Blume) dominates the high shrub layer. It is in the herbaceous strata, however, that the well-watered valley differs very strongly from the drier slope. The darker, deeper valley soil supports a nearly continuous carpet of lush herbaceous growth, ranging from just above ground level to over 1 m in height.

In summary, the total number of macrophyte species for each of the 2 study areas was: slope 29 and valley 78, with many species common to both. By combining the total species for both slope and valley, a breakdown of the above data reveals that there was a total of 22 species of trees; 17 shrubs and woody vines; 47 herbs, woodrush, grasses; 13 species of ferns, clubmosses and true mosses.

Meteorology.—The Fordham Ecology Center is located just inside the southern boundary of the climatic division of New York State known as the "Hudson Valley." The annual normal temperature for the study area is about 11°C. The temperatures on the slope ranged from a high of 32°C on the early date of May 10th to a low of −21°C on January 22nd. In the valley, a similar pattern was recorded, but usually 2.24°C lower in each case. The highest temperatures each day were reached between 1–3 PM, while the lowest were between 4–7 AM.

On days without precipitation, the relative humidity in the valley was usually 5–10% higher than that of the slope. The precipitation is about 112 cm annually, and well-distributed throughout the year, with a fairly regular monthly average of slightly over 8.9 cm. During 1970, however, only 75 cm fell in the study area.

Traps.—Each of the 12 pitfall bait traps consisted of a 3.78 l cylindrical tin can (size no. 10). In order to allow for rain and runoff water drainage, 25 tiny nail holes were hammered into the bottom of each trap in a regular pattern. A hole was dug for each trap so that the rim of the can was exactly flush with the surrounding woodland floor substrate. The outer circumference of each trap was packed with soil so that no intervening gaps remained. A .47 l uncoated cardboard container was placed inside each trap to hold the bait. A 23 × 23 cm square of galvanized 1.3 cm hardware screen was placed on top of each trap. Four 2.0 cm thick small stones were placed at each of the 4 corners of the screen to permit a crawl-space for the anticipated beetles to enter the trap. This in turn was covered by a 23 × 23 cm square piece of 0.6 cm masonry hardboard which acted as a rain-shield. Finally, in order to protect the pitfall trap from racoons and other bait-raiders, a large, heavy rock was placed over each rain-shield.

Bait.—Six traps were baited with fresh cantaloupe melon (*Cucumis melo* L.), sliced into sixths and the seeds removed. On the 1st day of baiting, 2 of the slices were placed in the cardboard container. On the 2nd day of collecting and replacement of the bait, 1 of the 2 slices of melon was removed from the trap and replaced by a fresh piece. Hence, a cyclic regimen was maintained so that 1 slice of melon was usually 0–3 days old, and the other slice 4–7 days old in each of the 6 melon traps.

The 2nd set of 6 traps was baited with 2 frozen, whole (18–23 cm) Atlantic smelt (*Osmerus mordax* Mitchell) with viscera and all body parts left intact. The same regimen was followed in baiting with fish as with melon, so that 2 fish in different stages of decomposition were always in each bait container.

Three melon and 3 fish pitfall traps were located on the slope, and an equal number in the valley area. These 12 traps were placed in pairs (1 melon–1 fish) at approximately 12 m distance from each other. These pairs in turn were located 24 m apart.

Collections were made from the traps twice weekly (3–4 days apart) between 1–7 PM, during the 8-month study period. The removed bait was carefully dissected in an aluminum baking pan in the field in order to insure collection of all specimens which had bored into the bait (usually nitidulids and scolytids). Other beetles were removed directly from the bait containers, and put together with the aforementioned Coleoptera into 57 g screw-top labeled jars containing 80% ethyl alcohol mixed with 2% glycerine by volume. Each area was sampled 46 times for a total of 552 separate collections.

Table 1. Families of Coleoptera collected from traps baited with fish for necrophilous beetles and melon for carpophilous species over an 8-month period (April thru November) at Fordham University's Calder Ecology Center, Armonk, Westchester Co., N.Y.

Family	Individuals		Species	
	No.	%	No.	%
1. Staphylinidae	7,407	37.1	62	28.6
2. Silphidae	4,300	21.5	7	3.2
3. Nitidulidae	3,575	17.9	24	11.1
4. Hydrophilidae	1,427	7.1	—[a]	—
5. Leptodiridae	979	4.9	6	2.8
6. Histeridae	684	3.4	17	7.8
7. Carabidae	463	2.3	23	10.6
8. Ptiliidae	390	2.0	4	1.8
9. Scarabaeidae	385	1.9	17	7.8
10. Scolytidae	266	1.3	6	2.8
Minor Families (5)	73	0.4	16	7.4
Adventitious families (18)	43	0.2	35	16.1
Totals	19,992	100.0	217	100.0

[a] All hydrophilids were in the genus *Cercyon,* but current taxonomic literature could not identify specimens to species.

Curating.—The field-collected beetles were curated in the Entomological Laboratories of Fordham University, Bronx, New York 10458. Each of the approximately 20,000 adult beetles was individually pinned, labeled, and then stored in 40 of Fordham's "California Academy of Sciences" style insect drawers.

Results and Discussion

Necrophilous and carpophilous families.—Almost 20,000 beetles were collected during the 8-month period (April thru November) from 6 traps baited with fish and 6 with melon. Six traps (3 pairs with each type of bait) were located on the dry slope and the other 6 in the wet valley. The trapped Coleoptera were concentrated in 10 major families (19,876 beetles or 99.4% of total) as shown in Table 1. In addition, there were also 5 minor families which included only 73 individuals or 0.4% of the total and were associated with fungi or decaying organic material. Finally, 18 other families (43 beetles or 0.2%) were categorized as "adventitious," i.e., phytophagous forms or wanderers on the forest floor which were probably accidentally caught in the traps. From the point of view of numbers of species, 217 species were collected and identified. Of these, 76.5% belonged to the 10 major families, 7.4% to the 5 minor families, and 16.1% to the adventitious families.

10 major families.—Considering that almost 20,000 individual Coleoptera were collected in the combination fish-melon and slope-valley traps, there

Table 2. Seasonal summary over an 8-month period of the 10 major families of Coleoptera collected from traps baited with fish for necrophilous beetles and melon for carpophilous species in a dry slope habitat and an adjacent wet valley.

	Slope			Valley			Total		Monthly	
Month	Fish	Melon	Total	Fish	Melon	Total	Fish	Melon	Total	%
Apr	227	114	341	337	95	432	564	209	773	3.9
May	978	247	1,225	547	255	802	1,525	502	2,027	10.2
Jun	509	765	1,274	356	639	995	865	1,404	2,269	11.4
Jul	1,309	574	1,883	1,371	747	2,118	2,680	1,321	4,001	20.2
Aug	793	1,536	2,329	975	1,148	2,123	1,768	2,684	4,452	22.4
Sep	960	858	1,818	791	914	1,705	1,751	1,772	3,523	17.7
Oct	260	672	932	217	1,018	1,235	477	1,690	2,167	10.9
Nov	159	172	331	138	195	333	297	367	664	3.3
Totals	5,195	4,938	10,133	4,732	5,011	9,743	9,927	9,949	19,876	100.0
Percent	51.3	48.7	51.0	48.6	51.4	49.0	49.9	50.1	100.0	

were some interesting, if not surprising, similarities in the overall totals (Table 2). For instance, 9,927 necrophilous beetles were collected in the fish traps, and almost an equal number (9,949) of carpophilous beetles were on melon. Similarly, the slope traps (fish-melon) accounted for 10,133 beetles, and the valley bait (also fish-melon) trapped 9,743. There are no significant statistical differences between these pairs of numbers. However, when the families and especially the species are examined more closely, then differences are seen in the preferences for the bait (fish or melon), and to a lesser degree for the habitat (slope or valley). A more complete picture of this *Part 1* overview will be given in subsequent papers which will analyze in detail the trophic and geographic differences not only between the 10 major families, but also among the species of each.

For the purpose of this introductory presentation, however, a brief summary of the 3 most numerous families (Staphylinidae, Silphidae, Nitidulidae) will be given below (Table 3). These 3 families comprised 76.5% of the individual beetles collected in this study, and 42.9% of the total species.

1) Staphylinidae.—The staphylinids contained more individuals (7,407 or 37.1%) and more species (62 or 28.6%) than any other family. They were attracted to melon over fish by a 2:1 ratio (4,704:2,703), and there was a 10% difference between the number in the valley (4,103 or 55.4%) and the slope (3,304 or 44.6%).

2) Silphidae.—Although this family ranked 2nd in the number of specimens (4,300 or 21.5%), it dropped significantly to 6th place in the number of species, having only 7 species represented or 3.2% of the total. In addition, unlike the Staphylinidae, these beetles were almost absent from the melon traps (only 0.8%). The slope also reflected a similar reversal in niche

Table 3. Comparison of the 3 most numerous Families of Coleoptera (Staphylinidae, Silphidae, Nitidulidae) collected from traps baited with fish for necrophilous beetles and melon for carpophilous species in a dry slope habitat and an adjacent wet valley over an 8-month period (April thru November).

Family		Slope			Valley			Total		
		Fish	Melon	Total	Fish	Melon	Total	Fish	Melon	Total
Staphylinidae	No.	1,171	2,133	3,304	1,532	2,571	4,103	2,703	4,704	7,407
	%	35.4	64.6	44.6	37.3	62.7	55.4	36.5	63.5	100.0
Silphidae	No.	2,457	24	2,481	1,807	12	1,819	4,264	36	4,300
	%	99.0	0.1	57.7	99.3	0.7	42.3	99.2	0.8	100.0
Nitidulidae	No.	262	1,888	2,150	144	1,281	1,425	406	3,169	3,575
	%	12.2	87.8	60.1	10.1	89.9	39.9	11.4	88.6	100.0
Totals	No.	3,890	4,045	7,935	3,483	3,864	7,347	7,373	7,909	15,282
	%	49.0	51.0	51.9	47.4	52.6	48.1	48.2	51.8	100.0

preference, accounting for 57.7% of the trapped silphids, while only 42.3% were collected in the valley traps.

3) Nitidulidae.—This was the 3rd most common family with 3,575 or 17.9% of the total individuals. Because of the few number of silphid species noted above, however, the Nitidulidae moved up to become the 2nd largest family as to number of species (24 or 11.1%). Of these, strong preferences were shown for melon (88.6%), while 60.1% were trapped on the slope. Hence, the nitidulids seemed to combine the preference of the Staphylinidae for melon with that of the Silphidae for the slope. Another way of looking at these data would be that the Nitidulidae occupied niches which were less competitive when considered in relation to the other two families.

Phenology.—During the 8-month period of this study (Table 2), only 773 beetles (3.9%) were collected in April. This increased to 2,027 (10.2%) during May, and 2,269 (11.4%) in June, so that both months were quite similar. However, the peak months were July (4,001 or 20.2%), August (4,452 or 22.4%) and September (3,523 or 17.7%). The October collecting (2,167 or 10.9%) was similar to that of May and June, while November (664 or 3.3%) returned to the low of April. This can be summarized by saying that 60.3% of the beetles were trapped during the peak months of July, August and September. But only about half as many (32.5%) were collected in May, June and October. As a result, April and November being the beginning and the end of the season, accounted for only 7.2% together.

In reference to the 3 most numerous families, the Staphylinidae peaked from August through October. On the other hand, May, July and August were the months in which the Silphidae were best represented, while the Nitidulidae were trapped most frequently in June, August and September.

These data indicate that August was the high month for collecting all 3 families. This was apparently due to phenological overlap, although the other months show some temporal niche-splitting.

Many species of beetles were represented by a very small 1st generation early in the spring or summer. After this initial appearance, they were not trapped again for a long period during the remainder of the summer, but reappeared with a large 2nd generation in the fall. Species with such a pattern are usually designated as bivoltine, but it should be pointed out that many spring specimens may have been overwintering adults (especially among the Carabidae). In this case, such species are actually univoltine. Winter diapause and summer aestivation are factors which should be studied in this regard. Hence, the continuing need in insect ecology for observation on the bionomics of each species in the field.

The results show that certain species are attracted to decomposing fish (necrophilous) and others to melon (carpophilous). However, in both cases, many of the beetles are actually predatory, and some are general scavengers. Closely related species are usually separated temporally, most often by fortnightly periods. Some of the seemingly weaker species emerge earlier than the stronger ones, and so gain a definite competitive advantage in time.

Fuller (1934), working for 4½ years in Australia, recorded far fewer species of beetles on carrion than is reported in this study, although the families represented were remarkably similar. Howden (1950) recorded 98 species of Coleoptera on carrion. The Familes Staphylinidae, Histeridae and Carabidae made up 50% of the beetles. She concluded that the effect of the surrounding flora on a carcass was expressed in moisture relationships, and our data on the dry slope and wet valley differences support this interpretation. She found that more beetle species and individuals participated in the succession in the spring than in the summer. In autumn, the carrion regained some of the lively and abundant qualities of the spring, but the fauna was not as rich.

Walker (1957) also showed that the succession of organisms associated with decaying material is influenced by variation in vegetation and microclimate. In addition, in an area of only a few hectares, the animals associated with similar decaying materials in adjacent habitats may be quite different. He used cantaloupe, fish and cornmeal as bait. The major groups of the trapped beetles included 15 species of staphylinids, 7 nitidulids and scarabs each, 3 histerids, 2 carabids, and 1 species each of hydrophilid, leiodid, ptiliid, mycetophagid—all taken on cantaloupe. In the fish baited traps, the following families of Coleoptera were recorded: 18 species of staphylinids, 8 species each of silphids and histerids, 6 scarabs, 2 hydrophilids and trogids, plus 1 nitidulid, carabid, dermestid, ptiliid, monotomid. Walker correctly noted that most of the field research on how attractive a bait is at certain times in its decay cycle fails to take into account whether the species are naturally available as adults at the time of the study. Our work at Fordham attempts to elucidate this neglected aspect of insect ecology.

Reed (1958) reported an analysis of dog-carcass microcommunities with particular reference to seral development, seasonal variation and environmental factors. He found that the summer months had peak populations with 217 species of insects of which only 96 were coleopteran species.

Payne (1965) used as carrion baby pigs (*Sus scrofa* L.). Carrion free of insects decomposed very slowly, merely drying and retaining its form for many months. However, 90% of the carrion open to insects was removed in 6 days. Only 2 coleopterous families, the Staphylinidae and Histeridae, were reported during the 2–3 weeks of his study. He determined that by the 5th day of exposure of pig carrion, beetles were the dominant adult insects present. Payne found that the activities of insects were more influenced by temperature than by any other environmental factor, while moisture ranked second. Payne agrees with Fuller (1934) in stating that insects hasten carrion disintegration by dissemination of bacteria, secretion of digestive juices, and by the mechanical processes of burrowing and tunneling through the carcasses. The Coleoptera and Diptera comprised 60% of the total fauna taken on carrion. Of 522 organisms collected, 422 species were insects, with 217 being beetles. Once again, the staphylinids and histerids were the dominant Coleoptera (92 species or 42.4%).

Extensive field studies on carrion beetle responses to poikilothermic (fish) and homoiothermic (chicken) bait have been done by Shubeck (1968, 1969, 1971, 1975a,b, 1976a,b) over many years using specially designed pitfall traps as well as specially designed ground and air traps. As in our study, he agreed with Walker (1957) that the differences in the species collected were due to the degree of carrion decay within the habitats, which in turn were caused by differences in microclimate. At the Family level, the overwhelming majority of beetles taken were Silphidae, Staphylinidae, Histeridae, Leiodidae, Scarabaeidae and Nitidulidae. Similar supporting studies have been done using lizards and toads (Cornaby 1974), and mammals (Johnson 1975).

The data obtained in our own field collections at the Fordham Ecology Center also fit very well with the population generalizations of Preston (1948). He noted that in any association there are just as many very rare species as there are common ones, but species of moderate abundance are vastly more numerous than either. Wilhm (1968) stated that the widespread similarity in numerical distribution patterns of individuals and species is one of the most interesting and still unexplained properties of ecological systems. Our results concur with these conclusions that a relatively small percentage of the species contain a large number of individuals, and a large percentage contain only a small number of individuals. Hence, the necrophilous and carpophilous Coleoptera can be used as ecological indicators of the numerical and temporal relations between species.

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